



A New Architecture for Visualization: Open Mission Control Technologies

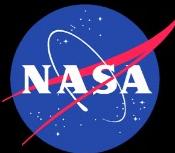
Jay Trimble, NASA Ames Research Center

ESAW 2017



A New Platform

- Why a new platform?
- Capabilities
 - All of your data in one place - no more application switching
 - View your data the way you want to see it
 - Compose your data without programming
 - Web based, desktop and mobile
 - Data source integration
 - Plug in architecture for customization
 - Open Source



Open Source

- Learn about it
 - <http://nasa.github.io/openmct/>
- Try it
 - <https://openmct-demo.herokuapp.com>
- Get the code
 - <https://github.com/nasa/openmct>



Open Source

- Enables Collaboration
 - Reduces/Eliminates ownership issues
 - Provides immediate access without restriction



Missions

- JPL
 - Mars 2020
 - Mars Science Lab (Beta Test)
 - Earth Science (evaluating)
- Ames Research Center
 - Resource Prospector Lunar Rover



All Your Data in One Place

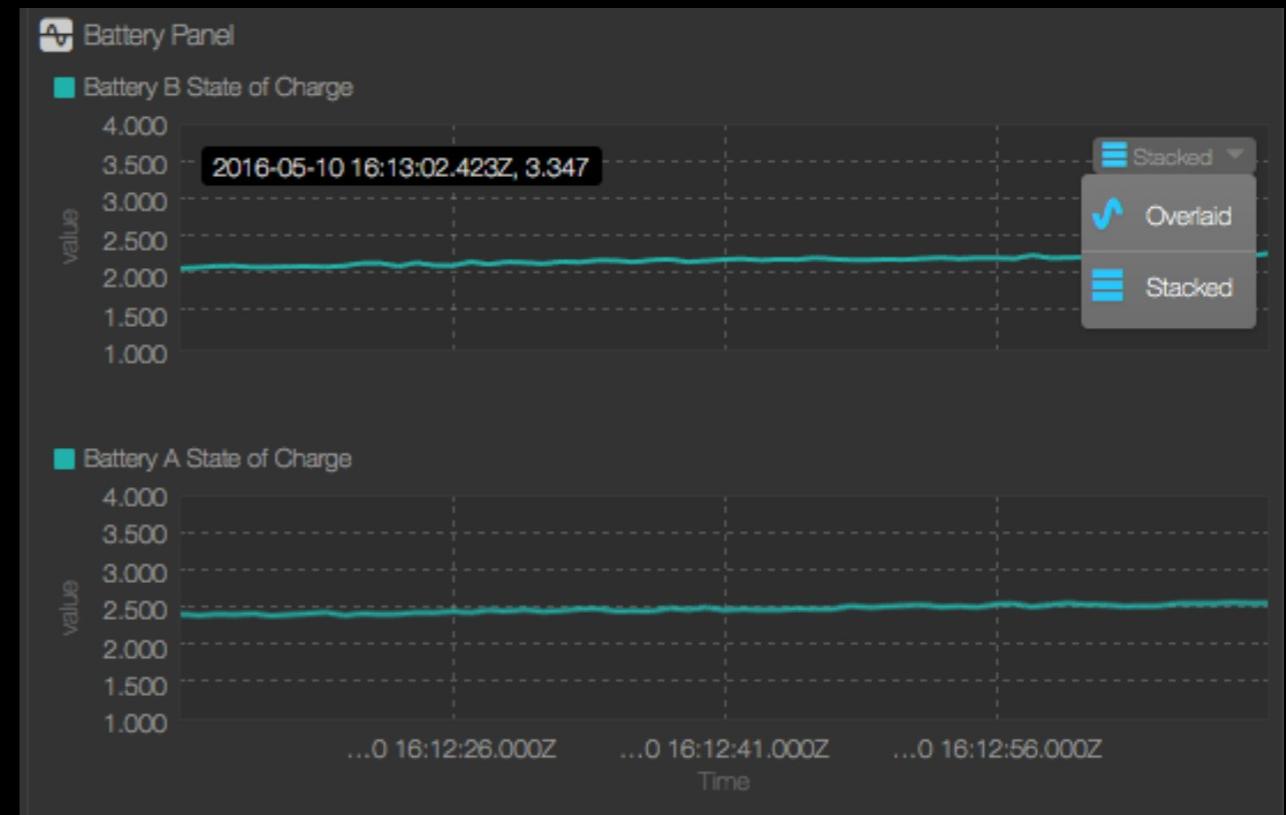
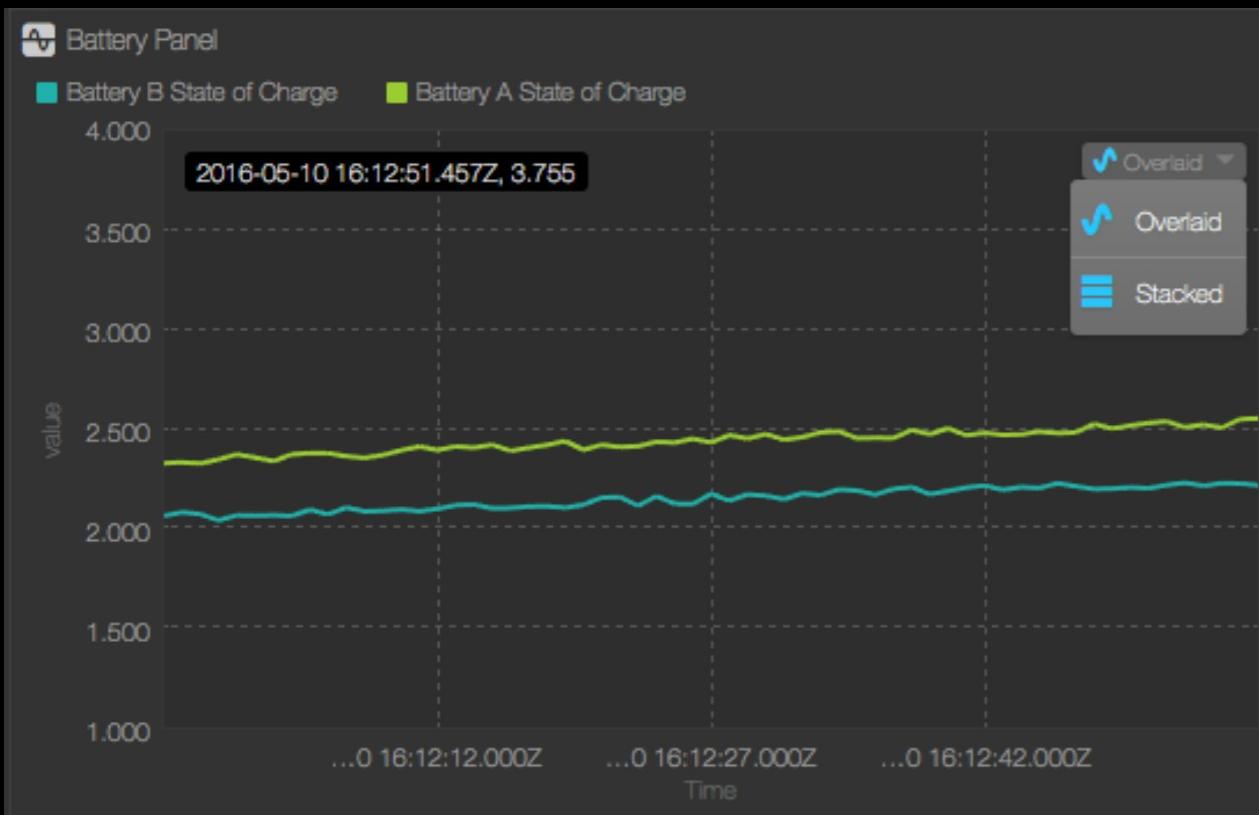
A layout is a composition
of data objects

The screenshot displays the CH MSL Layout 2 interface, a web-based application for managing and visualizing data objects. The interface is divided into several sections:

- Left Sidebar:** Contains a search bar labeled "Search your Data Objects" and a tree view of data objects under "CH MSL Layout 2". Key categories include SFP, ICE (with sub-categories like ICE STATES, ICE_ANALOG, ICE_MON), RBA, Spin-ICE, Telecom, Thermal, Systems, AMMOS Shared, MSL Users (with cfhacska selected), CH MSL Layout 2 (selected), CH Stacked Plot 1, DMX-1542 - EVR_LAST_WAR..., CH Blank Layout, CH Layout 2a, CH Table Group, CH Channel Table, CH Web Page, Channel List (with STATES, SPIN and PROFILE, MOTOR, SCIENCE, SFP), and peterr (with Pete's Experimental Layout and Sample Overlay).
- Middle Section:** Features four data visualization panels:
 - DMX-1101 - EHA_RT_PROD_CNT: A line graph showing a linear increase from approximately 14 to 44 over time.
 - D-1791 - DMD_SAR_READ_MEM_LOC_1: A step graph showing discrete data points at various times.
 - DMX-1021 - EHA_REC_NUM_ALW...: A line graph showing a sharp drop from 6 to 0 followed by a recovery.
 - F-0840 - FSW_IDLE_SCRUB_ERR_ADDR_2: A step graph showing discrete data points at various times.
- Right Section:** Contains two main panels:
 - INSPECTION:** Displays layout properties such as Title (CH MSL Layout 2), Updated (2016-01-21 17:43:47 UTC), Type (Display Layout), and Location (MSL Users > cfhacska).
 - PROPERTIES:** A table listing data objects with their IDs, titles, values, and SCET (Spacecraft Event Time). Examples include P-3219 (PWR_RDE_SENSED, Value: 1, SCET: 2016-21), R-3005 (RAD_OP_STATE, Value: 1, SCET: 2016-21), and A-0033 (ICE_RBE_RDE_TEMP_1, Value: 15.33680941141958, SCET: 2016-21).
- Bottom Navigation:** Includes a timeline with specific time points: 2015-300T06:58:42.617, 2015-300T09:08:53.774, 2015-300T11:19:04.931, 2015-300T13:29:16.089, and 2015-300T15:39:27.246. It also includes a "SCET" dropdown and a "VISTA" logo.



View as you want it





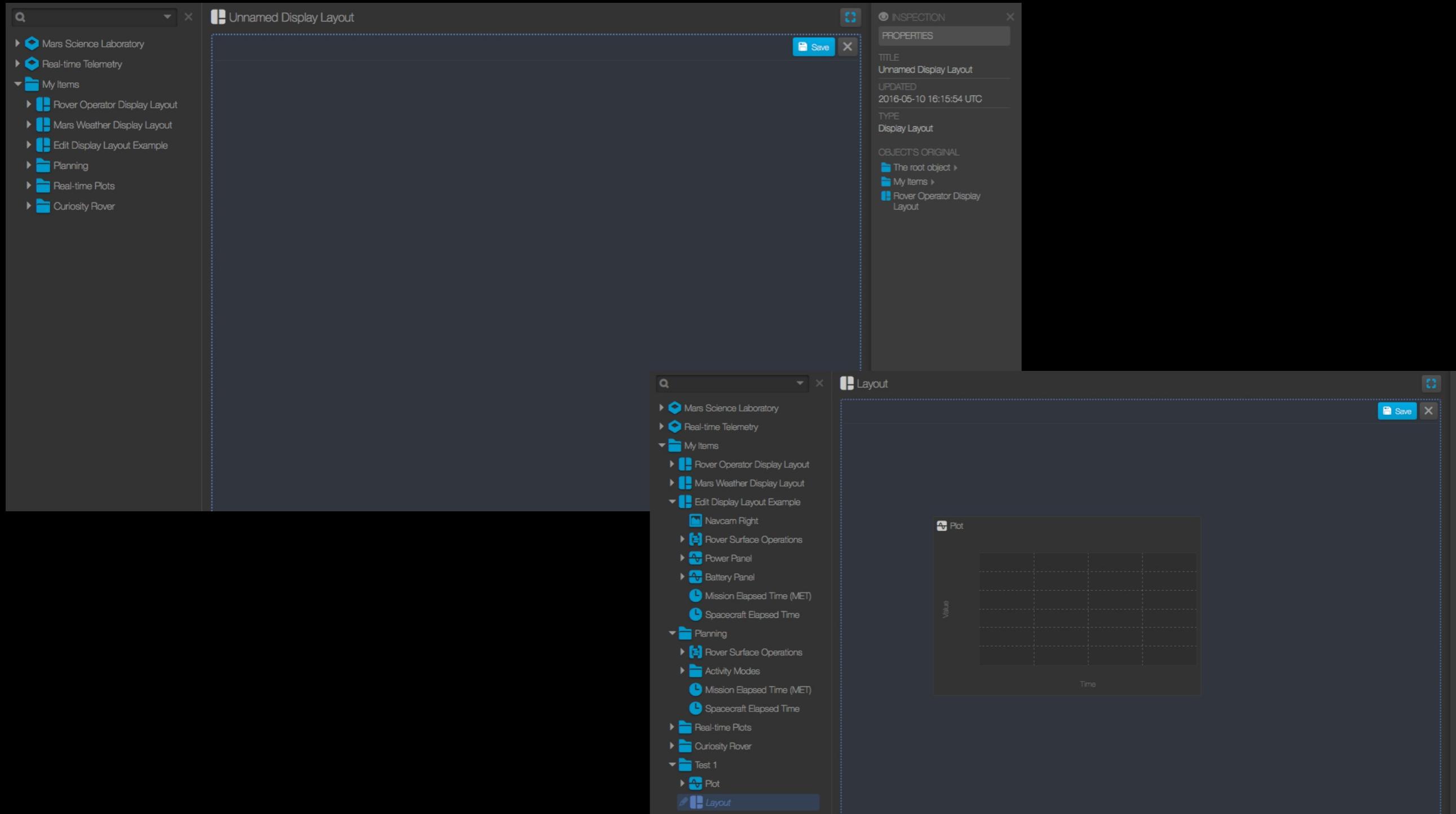
Composition - Create

The image shows a screenshot of the AMMOS software interface. On the left, there is a large white window titled "AMMOS Users" with a "CREATE" button in the top-left corner. This window contains a list of items with icons: Folder, Display Layout, Web Page, Historical Telemetry Table, Real-time Telemetry Table, Overlay Plot, Stacked Plot, Data Set, LAD Table, LAD Table Set, and Data Table. On the right, there is a dark gray window titled "My Items" with a "Create" button in the top-left corner. This window also contains a list of items with icons: Web Page, Example Imagery, Event Message Generator, Sine Wave Generator, Clock, Timer, Folder, Display Layout, Telemetry Panel, Timeline, Activity, and Activity Mode. The "Activity" and "Activity Mode" items in the right window are highlighted in blue, indicating they are currently selected or active.

Left Window (AMMOS Users)	Right Window (My Items)
Folder	Web Page
Display Layout	Example Imagery
Web Page	Event Message Generator
Historical Telemetry Table	Sine Wave Generator
Real-time Telemetry Table	Clock
Overlay Plot	Timer
Stacked Plot	Folder
Data Set	Display Layout
LAD Table	Telemetry Panel
LAD Table Set	Timeline
Data Table	Activity
	Activity Mode



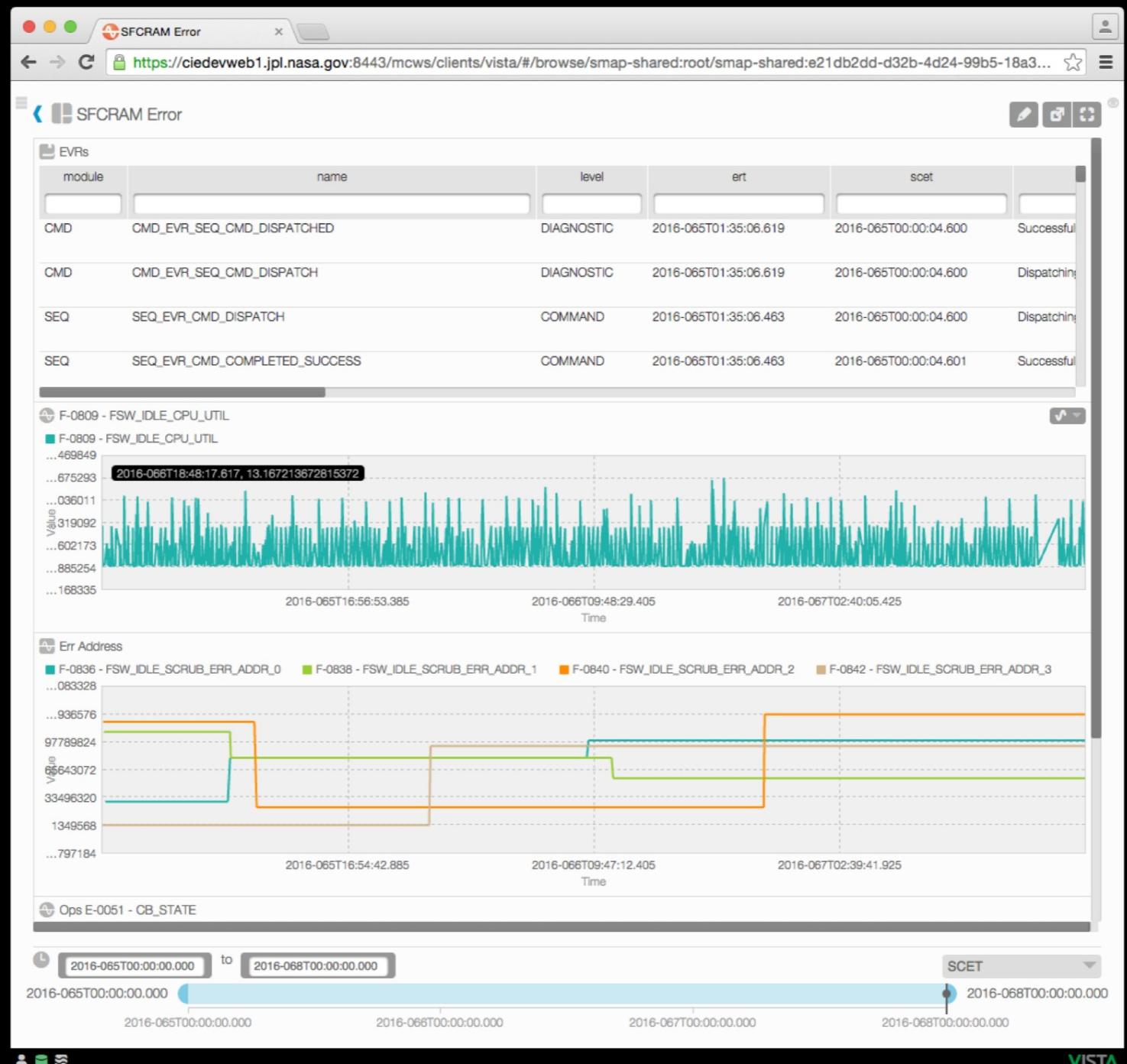
Compose in Layouts



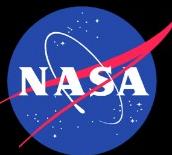
<http://nasa.github.io/openmct/>



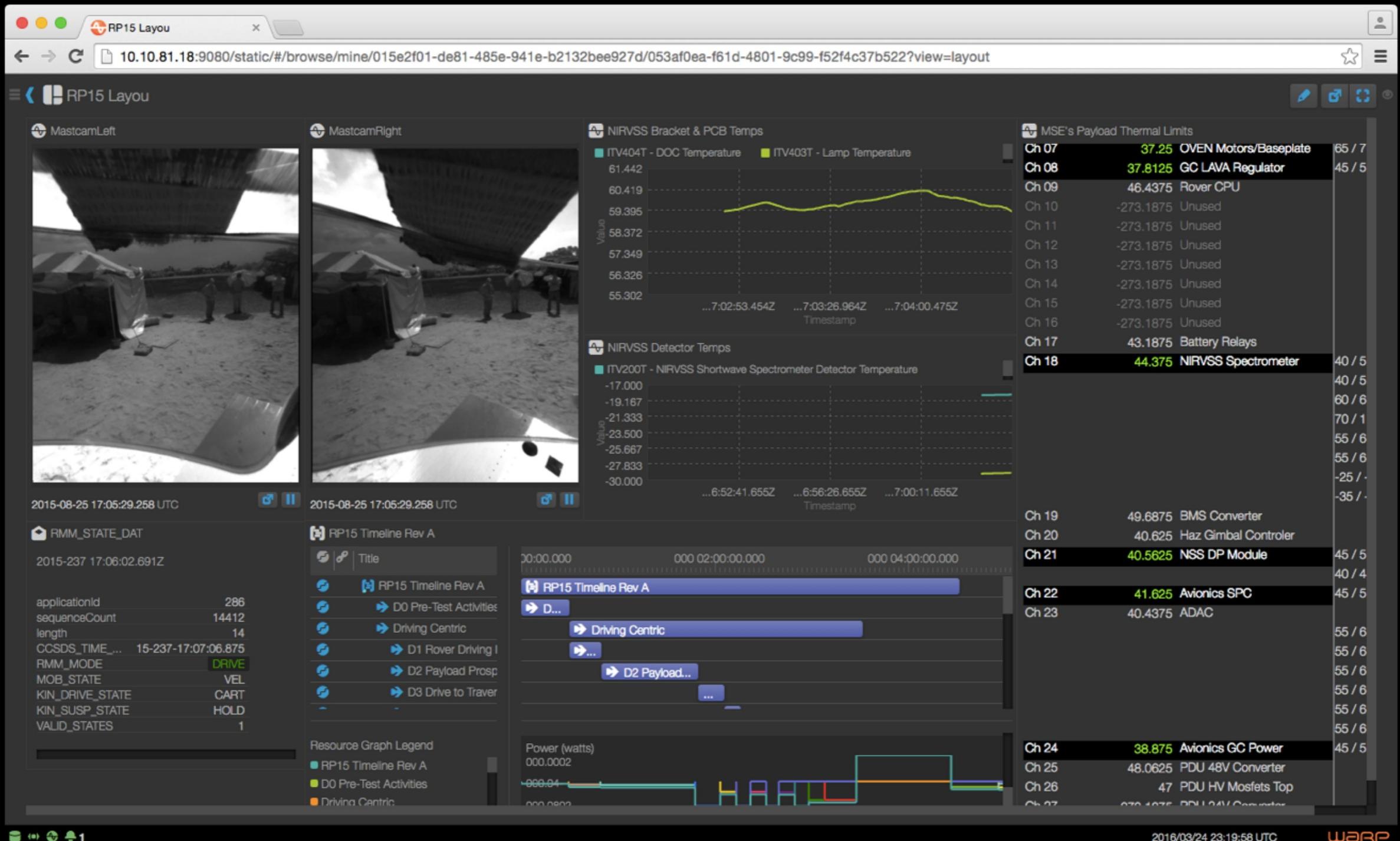
Mars Science Lab Composition (JPL)



VISTA

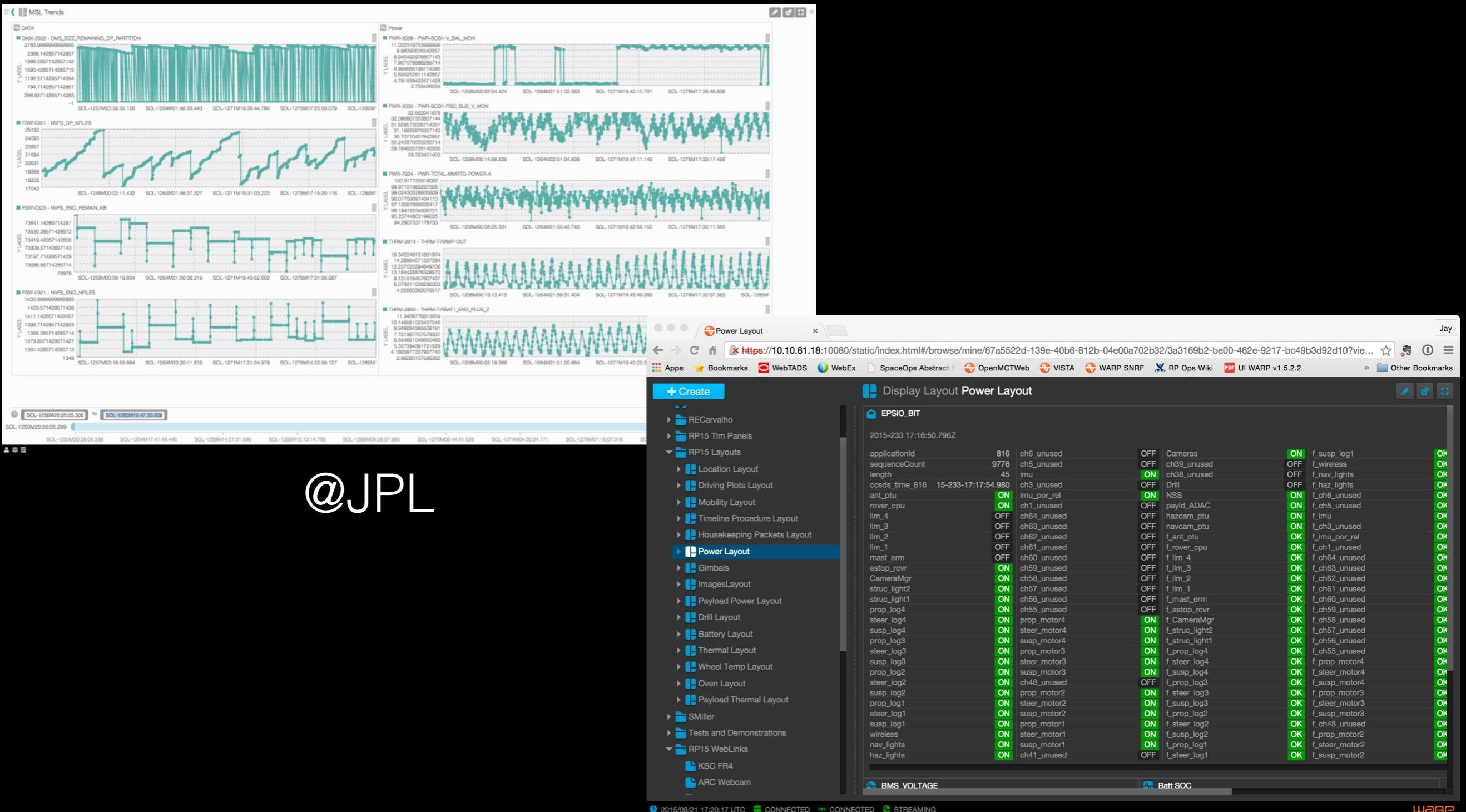


Resource Prospector Composition (ARC)





On the Desktop

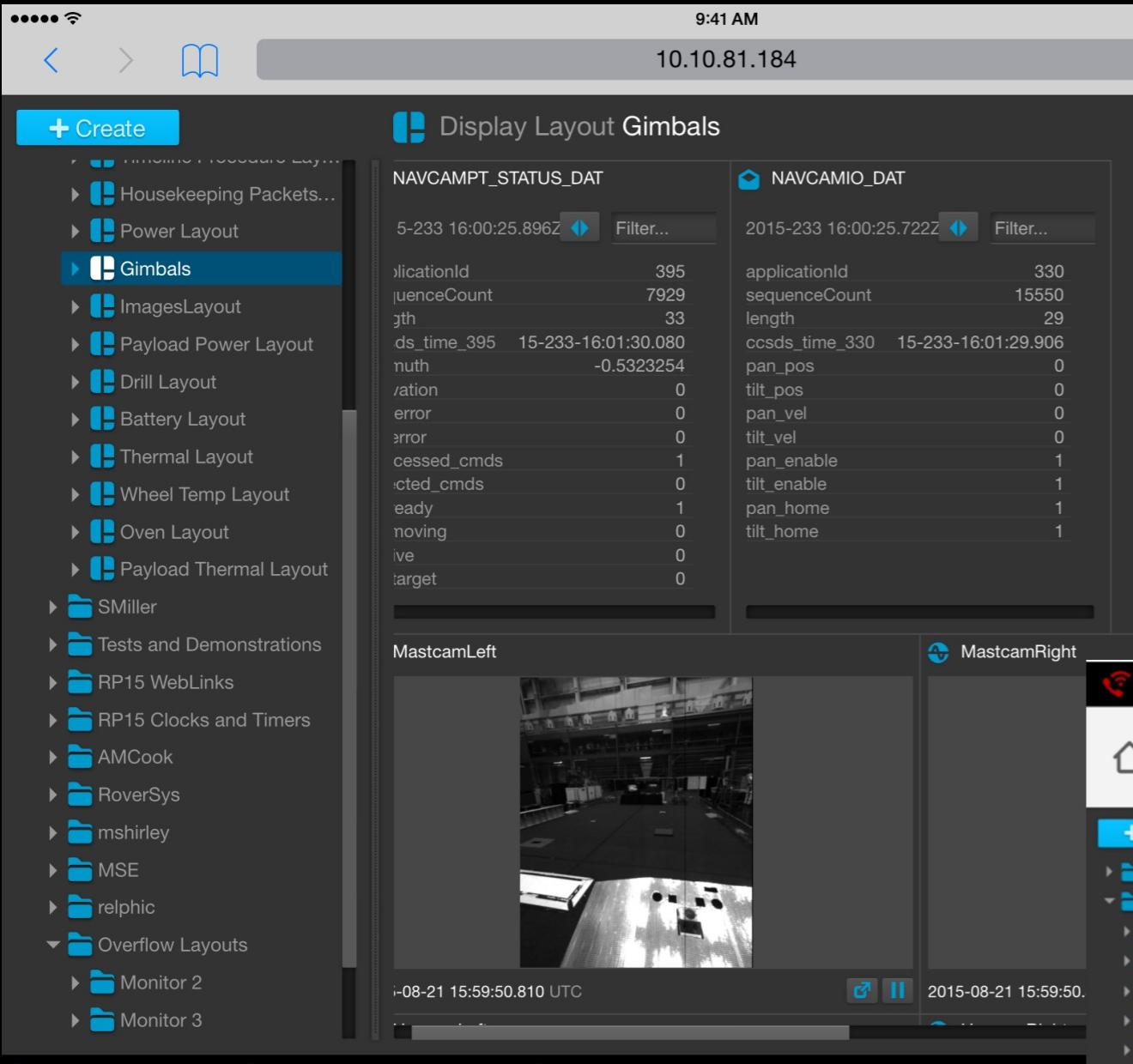
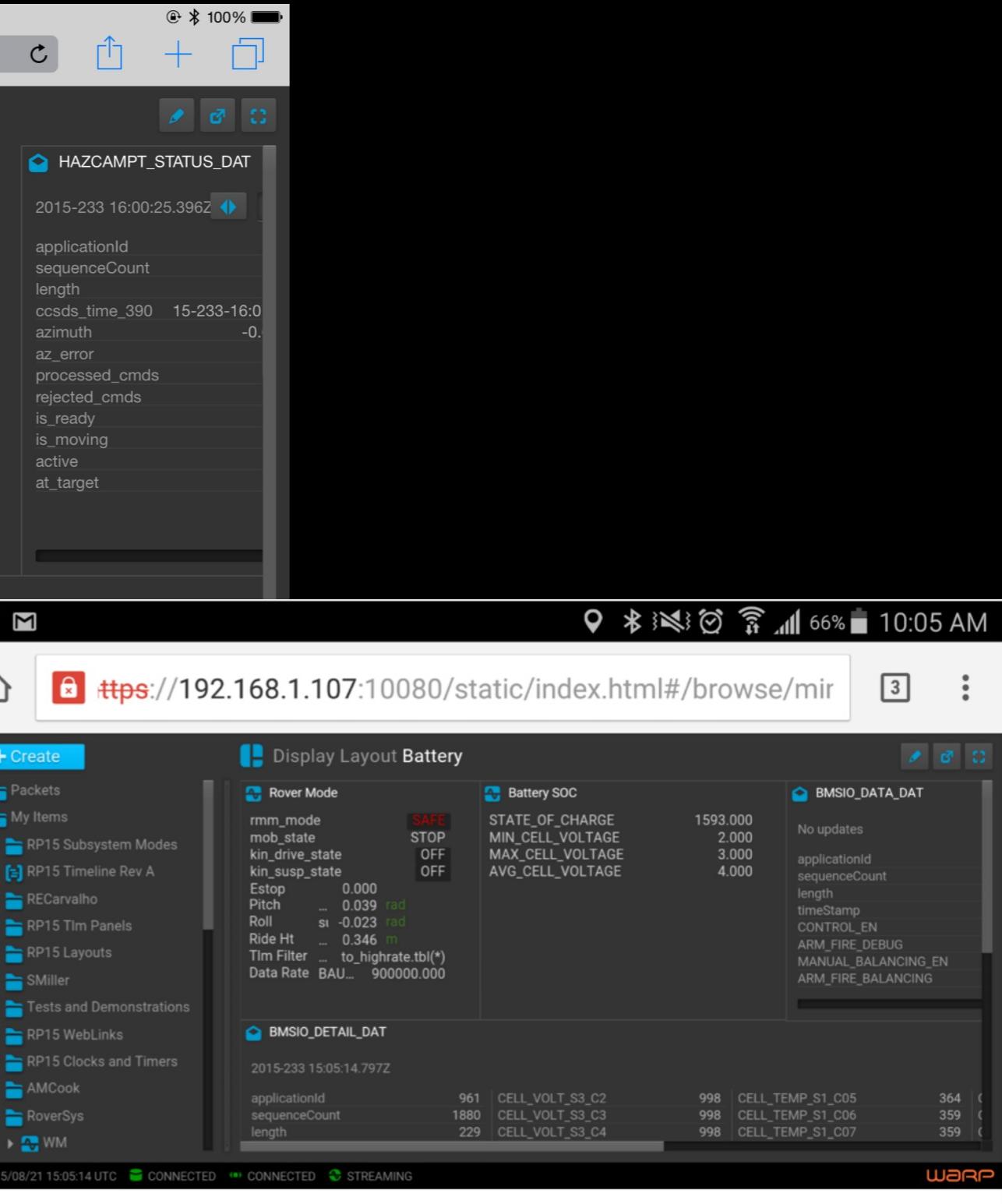


@JPL

@ARC



Mobile

9:41 AM 10.10.81.184 100%  10:05 AM 

The image displays two mobile devices, an iPad and a Phone, both running software interfaces for monitoring and controlling a rover or similar system.

iPad Screenshot:

- Top Bar:** Shows signal strength, time (9:41 AM), IP address (10.10.81.184), battery level (100%), and navigation icons.
- Left Sidebar:** A tree view of system components:
 - Housekeeping Packets...
 - Power Layout
 - Gimbals** (selected)
 - ImagesLayout
 - Payload Power Layout
 - Drill Layout
 - Battery Layout
 - Thermal Layout
 - Wheel Temp Layout
 - Oven Layout
 - Payload Thermal Layout
 - SMiller
 - Tests and Demonstrations
 - RP15 WebLinks
 - RP15 Clocks and Timers
 - AMCook
 - RoverSys
 - mshirley
 - MSE
 - rephic
 - Overflow Layouts**
 - Monitor 2
 - Monitor 3
- Central Area:** Three data tables:
 - NAVCAMPT_STATUS_DAT**: Rows include applicationId (395), sequenceCount (7929), length (33), ccsds_time_395 (15-233-16:01:30.080), azimuth (-0.5323254), etc.
 - NAVCAMIO_DAT**: Rows include applicationId (330), sequenceCount (15550), length (29), ccsds_time_330 (15-233-16:01:29.906), pan_pos (0), tilt_pos (0), etc.
 - HAZCAMPT_STATUS_DAT**: Rows include applicationId, sequenceCount, length, ccsds_time_390 (15-233-16:01:29.906), azimuth (-0.5323254), az_error, processed_cmds, rejected_cmds, etc.
- Bottom Area:** Two video feeds labeled "MastcamLeft" and "MastcamRight" showing a view of the rover's surroundings.

Phone Screenshot:

- Top Bar:** Shows signal strength, time (10:05 AM), battery level (66%), and navigation icons.
- URL Bar:** https://192.168.1.107:10080/static/index.html#/browse/mir
- Central Area:** A mobile browser interface showing a "Display Layout Battery" page with data tables for Rover Mode and BMSIO_DATA_DAT.
- Bottom Area:** A data table for BMSIO_DETAIL_DAT.

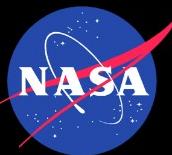
iPad

Phone



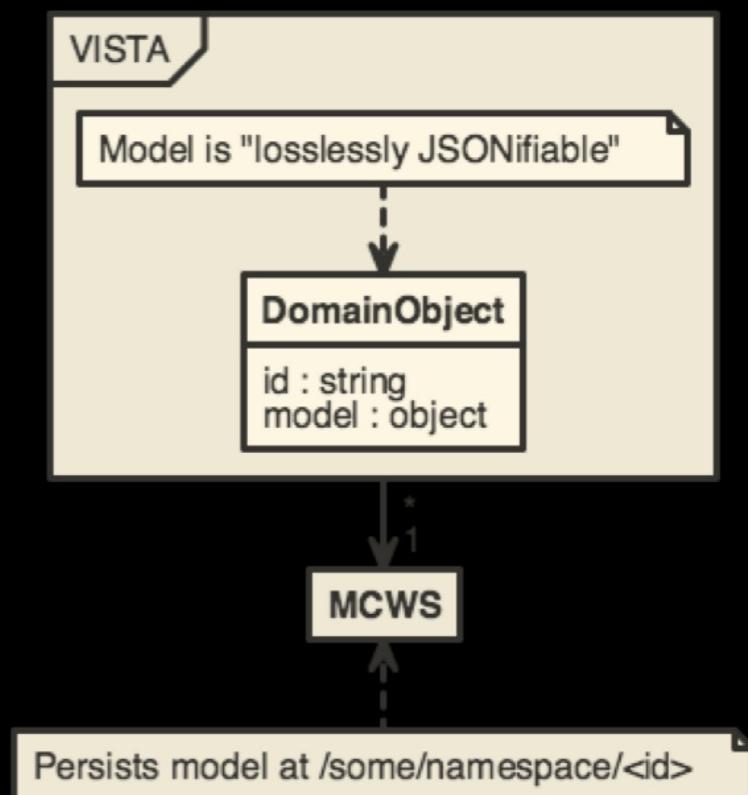
Architecture

- JavaScript
- HTML and CSS
- Domain Objects
 - Identifier, Model, Dynamic Behavior
 - Views



Persistence

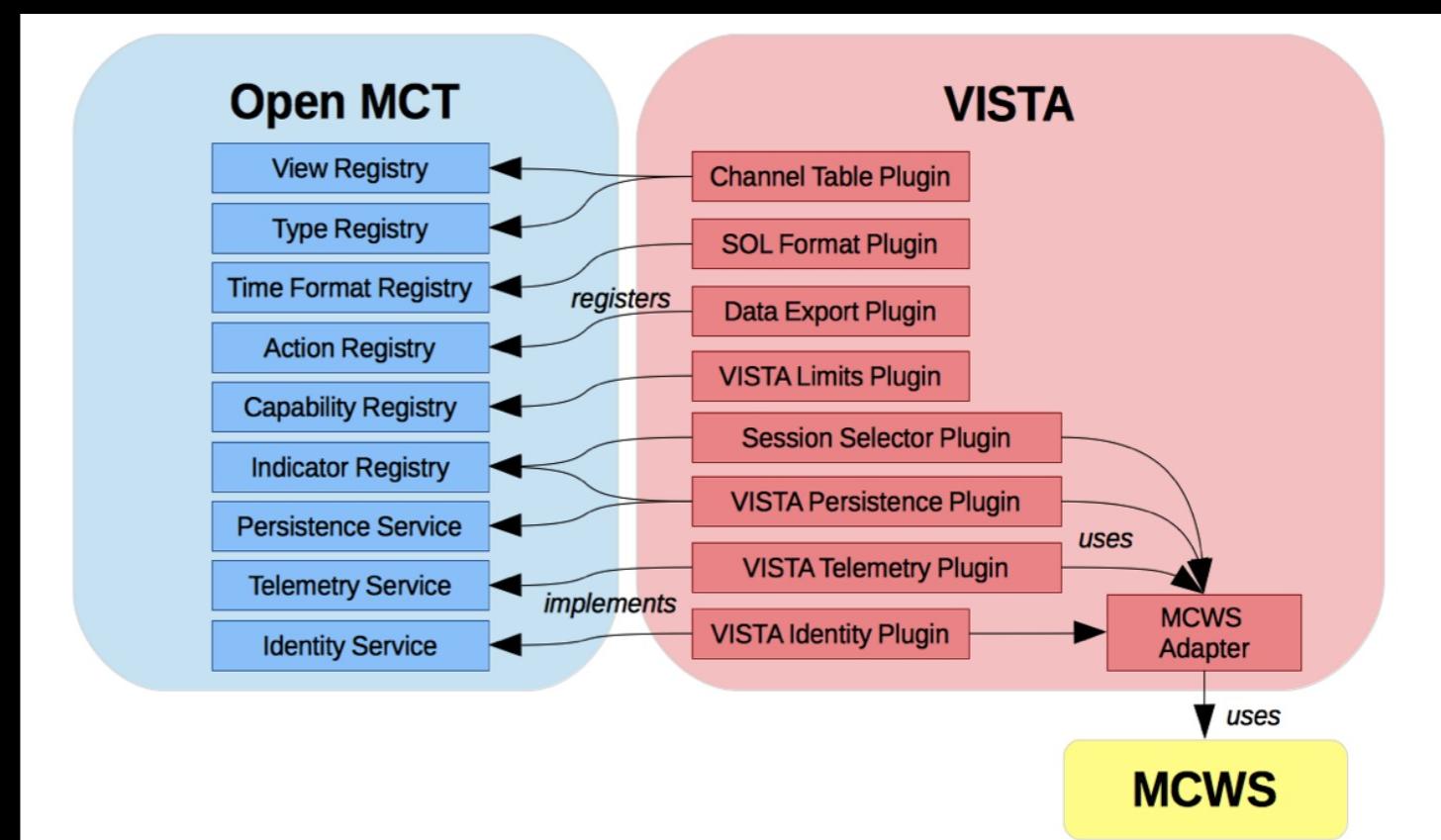
- User created objects stored as JSON documents on mission control web services (MCWS) at JPL





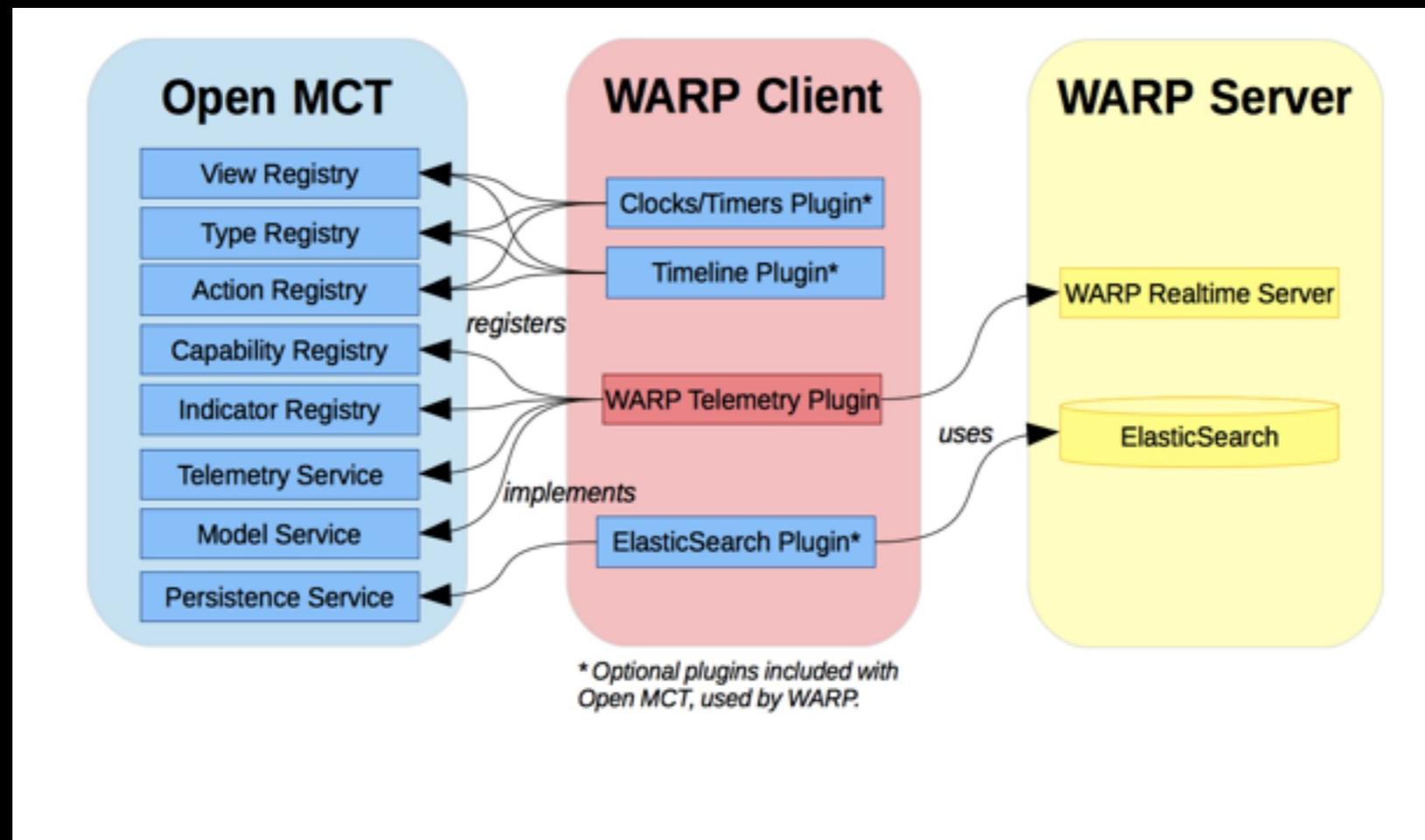
Mission Adapters JPL

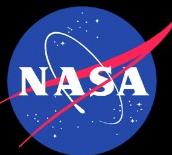
- Open MCT integrates with mission data sources via adapter plug ins
- Adapters handle requests for real-time subscriptions and/or historical queries
- Views initiate requests for the data they will display, Open MCT Mediates
- Plug in mechanism avoided coupling to specific server side data





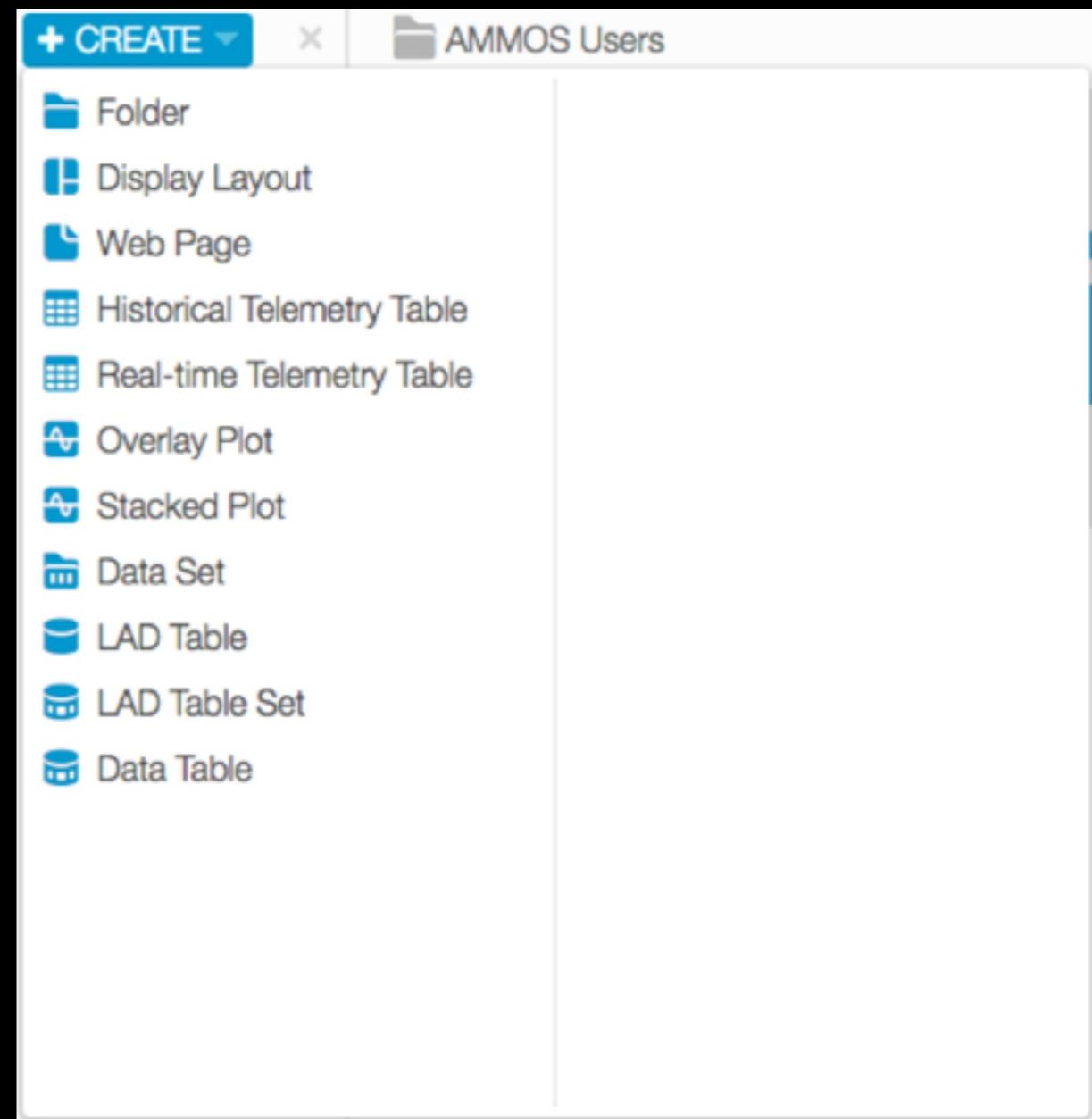
Mission Adapters ARC





VISTA Objects

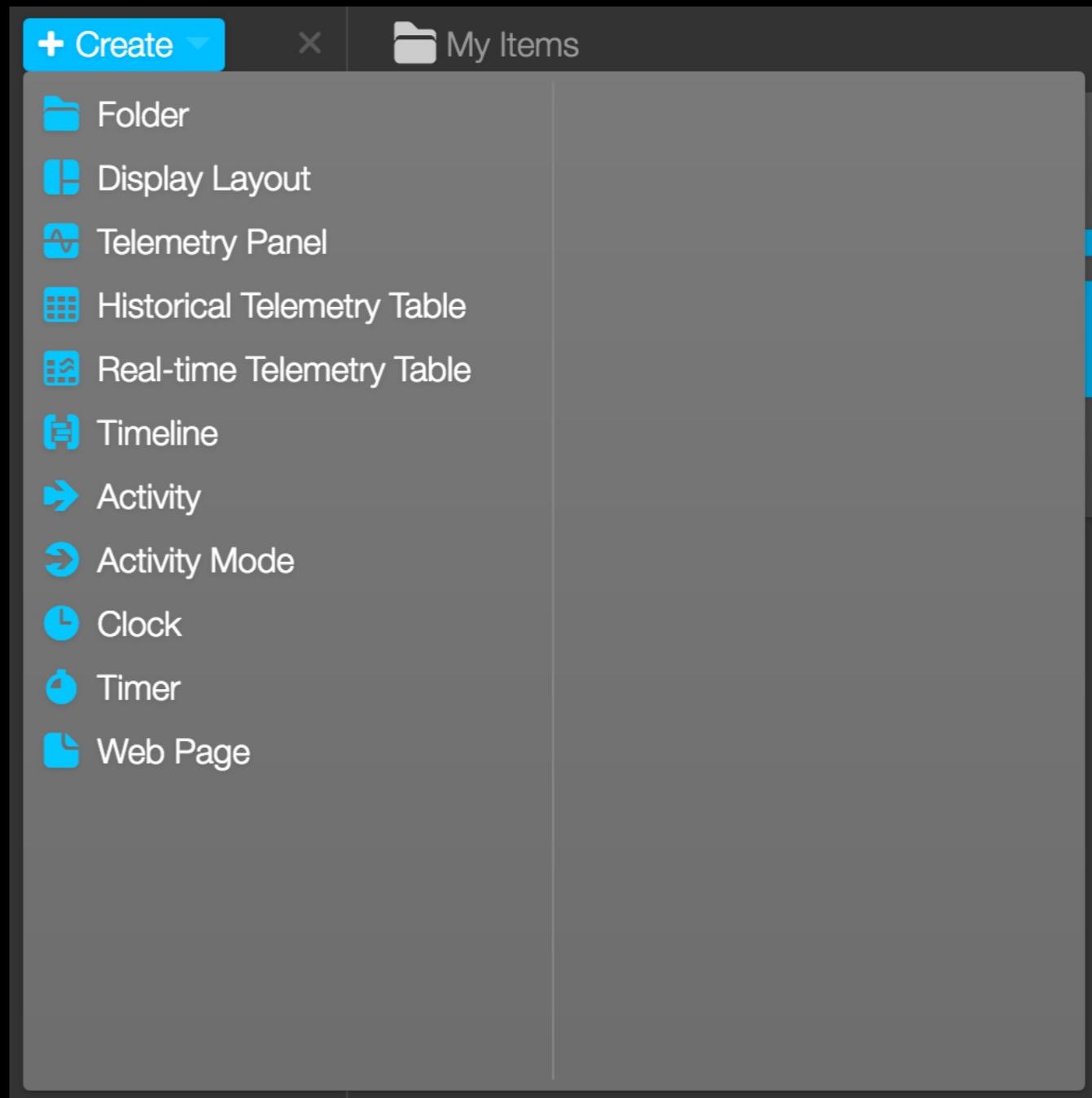
- VISTA is Open MCT customized by plug ins
- Customized for the JPL Mission Domain
- More objects on the way





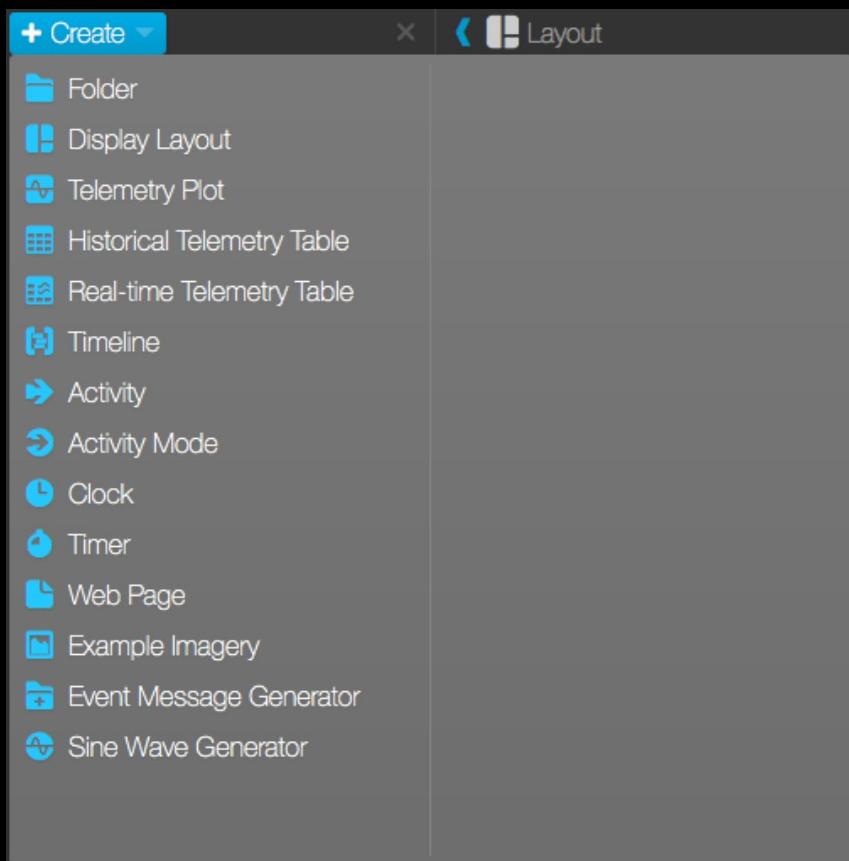
WARP Objects

- WARP is Open MCT, customized by plug ins
- Deployed at ARC

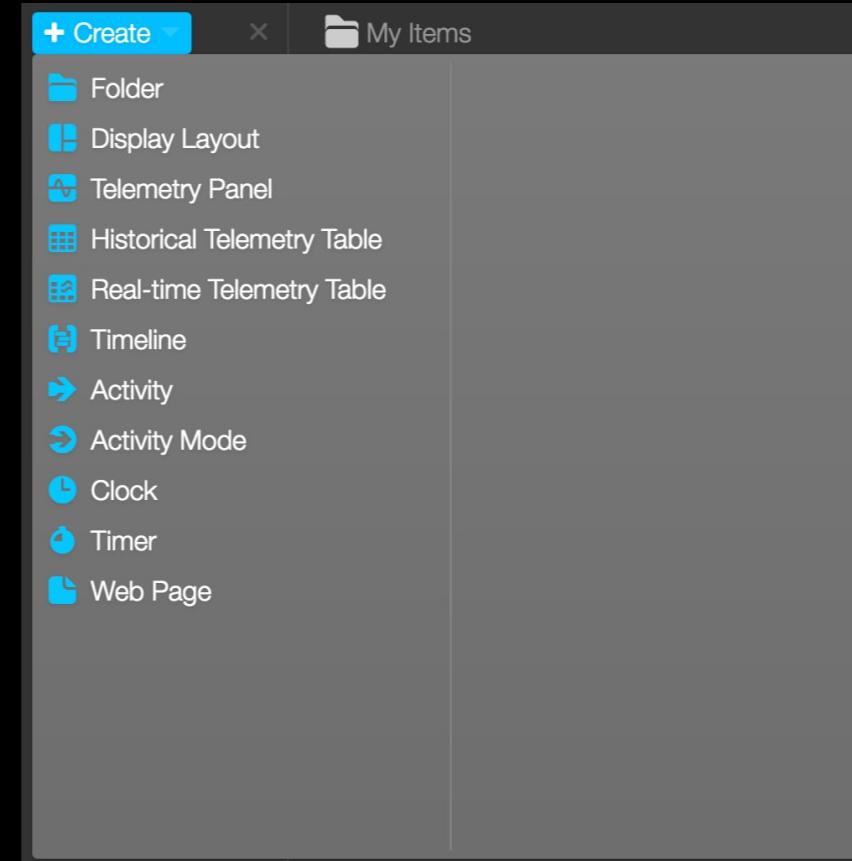




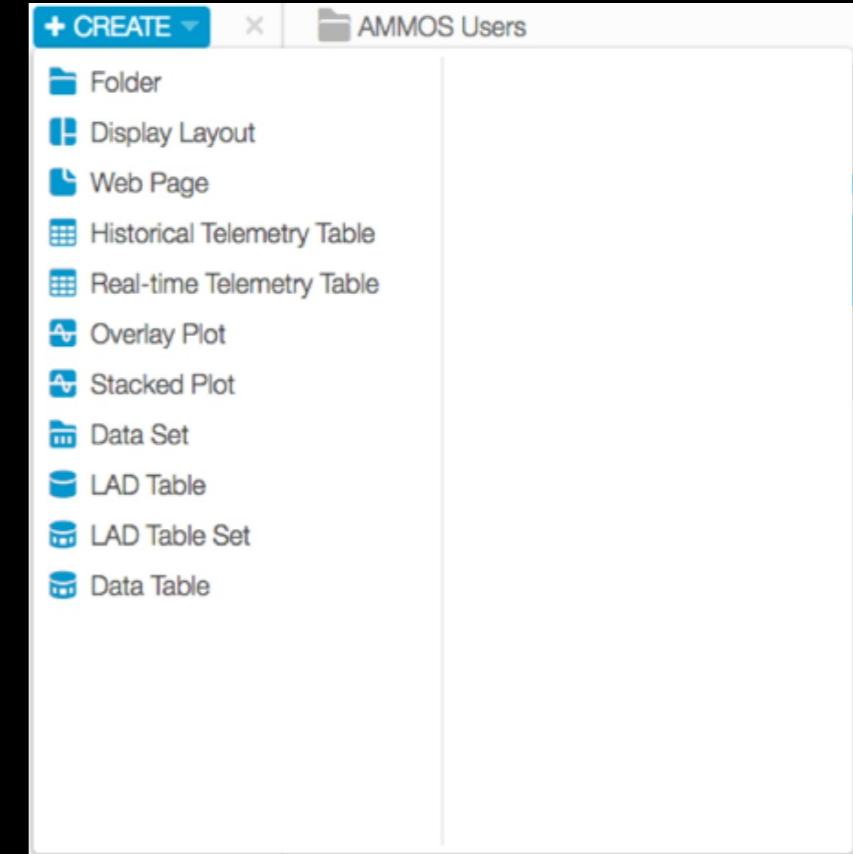
Compare



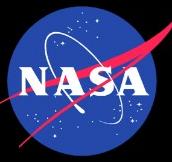
Open



WARP



VISTA



WARP Objects

The screenshot displays the WARP Objects application interface, which integrates various data sources for mission control.

Left Panel: A sidebar titled "My Items" lists available objects:

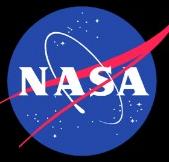
- + Create
- Web Page
- Example Imagery
- Event Message Generator
- Sine Wave Generator
- Clock
- Timer
- Folder
- Display Layout
- Telemetry Panel
- Timeline
- Activity
- Activity Mode

Central Timeline View: The main area shows a timeline from 2015-08-25 16:57:44.457 UTC to 2015-08-25 16:57:44.457 UTC. It includes:

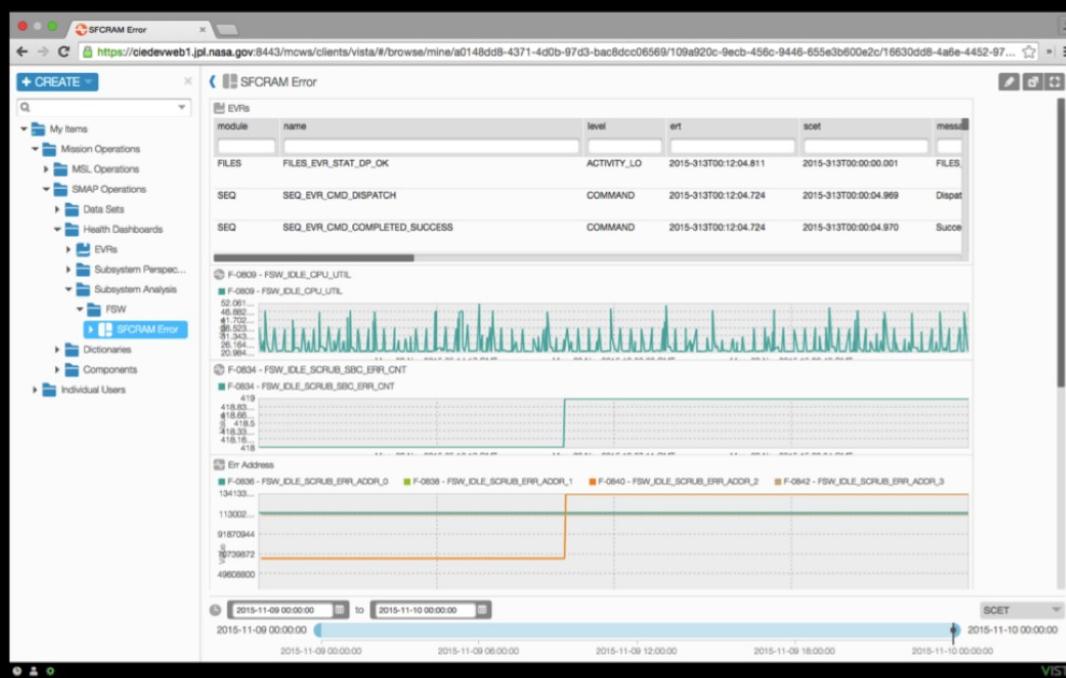
- RP15 Timeline Rev A:** A detailed timeline with activities like "D0 Pre-Test Activities", "Driving Centric", "D1 Rover Driving Prep", "D2 Payload Prospecting Prep", and "D3 Drive to Traverse Target".
- RP15 Layout:** Two video feeds showing the rover's perspective on the surface.
- Telemetry Panel:** Real-time data plots for "ITV404T - DOC Temperature" (blue line) and "ITV403T - Lamp Temperature" (green line), along with other sensor data.
- Rover Sensor Temperatures:** A table listing temperatures for various rover components.
- Resource Graph Legend:** A timeline showing power usage over time.

Bottom Feeds:

- KSC FR4:** Webcam feed showing the Flight Readiness Facility at Kennedy Space Center.
- ARC Webcam:** Webcam feed showing the NASA Johnson Space Center Mission Control Center.



VISTA at JPL



Uplink

Two tables showing Uplink command logs and status.

Uplink (Left Table):

ID	Title	Value	SCET
N-0138	CMD_MON_COMMAND_LOSS_STAT	1	2016-78T16:18:40.7920
N-0014	CMD_CLT_COUNT	220136	2016-78T16:21:32.7920
D-1724	CMD_LAST_HW_CMD_LOGGED_OPCODE	1637	2016-78T16:18:40.7920
D-1725	CMD_NUM_VALID_HW_CMOS_RECV	2	2016-78T16:18:40.7920

Uplink Session (Right Table):

ID	Title	Value	SCET
D-1718	CMD_NUM_INVALID_UPLINK_SESS	718	2016-78T16:18:40.7920
D-1727	CMD_NUM_INVALID_UPLINK_SESS	718	2016-78T16:18:40.7920
D-1721	CMD_NUM_INVALID_UPLINK_SESS	717	2016-78T16:18:40.7920
D-1709	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1719	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1711	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1710	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1712	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1733	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1717	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1722	CMD_NUM_INVALID_UPLINK_SESS	1	2016-78T16:18:40.7920
D-1720	CMD_NUM_INVALID_UPLINK_SESS	64943	2016-78T16:18:40.7920
D-1717	CMD_NUM_INVALID_UPLINK_SESS	511578019	2016-78T16:18:40.7920
D-1715	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1763	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
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D-1735	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1736	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1737	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1738	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1739	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1740	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1741	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1742	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1743	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1744	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1745	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1746	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1747	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1748	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1749	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1750	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1751	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1752	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1753	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1754	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920
D-1755	CMD_NUM_INVALID_UPLINK_SESS	0	2016-78T16:18:40.7920



Mobile WARP for Rover Ops

The image displays a mobile device screen showing real-time data from a rover system, overlaid with a photograph of a physical rover test site.

Mobile Device Screen (Left):

- Top Bar:** Shows signal strength, battery level (66%), and time (10:05 AM).
- Address Bar:** https://192.168.1.107:10080/static/index.html#/browse/mir
- Sidebar (My Items):**
 - + Create
 - Packets
 - My Items
 - RP15 Subsystem Modes
 - RP15 Timeline Rev A
 - RECarvalho
 - RP15 Tlm Panels
 - RP15 Layouts
 - SMiller
 - Tests and Demonstrations
 - RP15 WebLinks
 - RP15 Clocks and Timers
 - AMCook
 - RoverSys
 - WM
- Main Content:**
 - Display Layout Battery**
 - Rover Mode:**

rmm_mode	SAFE
mob_state	STOP
kin_drive_state	OFF
kin_susp_state	OFF
Estop	0.000
Pitch	... 0.039 rad
Roll	st -0.023 rad
Ride Ht	... 0.346 m
Tlm Filter	... to_highrate.tbl(*)
Data Rate	BAU... 900000.000
 - Battery SOC:**

STATE_OF_CHARGE	1593.000
MIN_CELL_VOLTAGE	2.000
MAX_CELL_VOLTAGE	3.000
AVG_CELL_VOLTAGE	4.000
 - BMSIO_DATA_DAT:**

No updates	
applicationId	
sequenceCount	
 - BMSIO_DETAIL_DAT:**

2015-233 15:05:14.797Z	
applicationId	961
sequenceCount	1880
length	229
CELL_VOLT_S3_C2	
CELL_VOLT_S3_C3	
CELL_VOLT_S3_C4	

Bottom Status Bar: 2015/08/21 15:05:14 UTC CONNECTED CONNECTED STREAMING

Photograph (Right): A photograph of a real-world rover test site. In the foreground, a small rover with a large solar panel array mounted on its back is positioned on a dirt path. Several people are standing around the rover, some near a red utility vehicle and others near a white metal frame structure. The background shows a grassy field and some industrial equipment.